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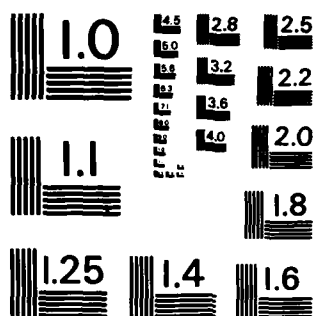
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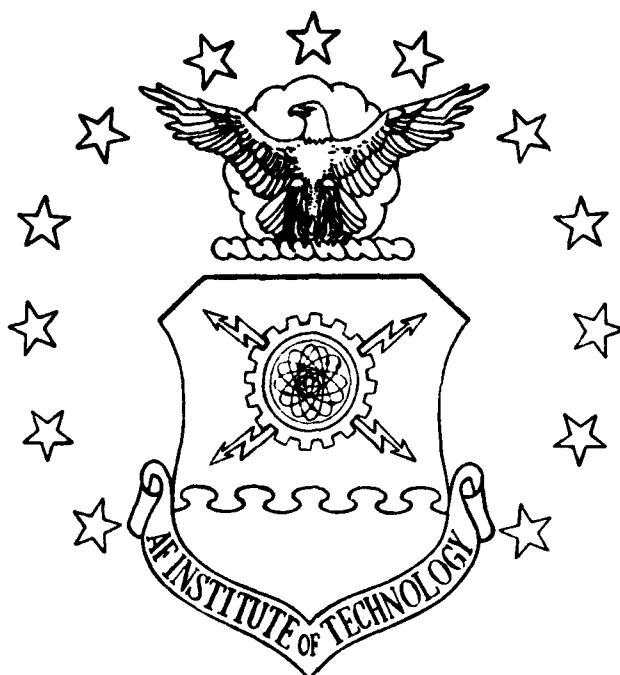


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A DESCRIPTION OF A
LOGISTICALLY IDEAL AIRCRAFT

THESIS

John D. Campbell
Captain, USAF

James D. Carlin
Captain, USAF

AFIT/GSM/LSY/B4S-5

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A DESCRIPTION OF A LOGISTICALLY IDEAL AIRCRAFT

THESIS

**Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology**

Air University

**In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Systems Management**

**John O. Campbell, B.S.
Captain, USAF**

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Captain, USAF**

September 1984

Approved for public release; distribution unlimited

Preface

The purpose of this study was to describe an aircraft that would be logistically ideal. The results of this study are expected to serve as a basis for further research when considering logistics issues during the life cycle of aircraft. In addition, this study could be used as an aid to reduce the problem of trying to maintain increasingly complex weapon systems.

This study was conducted using a Delphi method to reach a consensus on topics of a theoretical nature. Topic areas included: acquisition, operational requirements, requirements determination, logistic supportability, battle damage, and maintainability, to name a few. Participants used for this study were senior Air Force logisticians on active duty or retired representing various viewpoints.

In conducting this study, we have received much help from others. We are deeply indebted to our faculty advisor, Jerry Peppers, who continued to help and guide us in times of extreme frustration. We would also like to thank our wives Lynne and Linnea for their understanding and patience on those days we were burdened with a large workload. Finally we would like to thank our children Owen, Daniel, and Nicholas; and Jay, for their patience and a promise for more attention in the future.

John D. Campbell
James D. Carlin

Table of Contents

	Page
Preface.	ii
Abstract	iv
I. Introduction	1
Purpose of the Study	3
Background	4
Problem Statement.	7
Research Questions	7
Summary.	8
II. Methodology.	9
Chapter Overview	9
Identification of Problems	9
Identification of Possible Solutions	11
Delphi Method.	13
Consensus Criteria	15
Questionnaire.	15
Advantages of Delphi	16
Arguments Against the Delphi Method.	18
Summary of the Delphi Method	18
Description of the Ideal Logistical Aircraft	19
Summary.	19
III. Findings	20
Round One of the Delphi Method	20
Round Two of the Delphi Method	31
IV. Analysis	44
Discussion	45
Logistically Ideal Aircraft.	48
V. Conclusions.	54
Recommendations.	56
Appendix A: Round One Questionnaire	58
Appendix B: Round Two Questionnaire	64
Bibliography	72
Vita	74

Abstract

The purpose of this research was to provide a description of a logistically ideal aircraft. To achieve this description, problems of current aircraft were explored. From those problems, possible solutions were identified. Finally, this information was incorporated into the description of an aircraft that is logistically ideal. Some of the topics covered in this research include: acquisition, operational requirements, requirements determination, logistics supportability, battle damage, and maintainability.

The study was conducted using a Delphi method to reach a consensus on topics of a theoretical nature. Participants for this study were senior Air Force logisticians on active duty or retired and distinguished civilian logisticians. The Delphi methodology was used to elicit expert opinion concerning major logistics problems in current generation aircraft and ways to avoid these problems in future generation aircraft.

A DESCRIPTION OF A LOGISTICALLY IDEAL AIRCRAFT

I. Introduction

The United States commits vast amounts of its resources to protect its interests worldwide. In the face of a constantly changing threat environment, older weapon systems become obsolete and are no longer capable of efficiently performing their missions. The acquisition of new weapon systems is critical to the defense of the United States and its interests abroad. The military departments continually reassess the threats to the United States and constantly search for efficient ways to counter the threats. Often, the development of a new weapon system is the most efficient way to counter a new or enhanced enemy threat. These new weapon systems are generally highly complex and very expensive.

In the drive to field a new weapon system, performance requirements usually override logistical requirements. After all, if the weapon system does not perform as required against the threat, there is not much point in developing that weapon system. However, if, due to a logistics problem, that weapon system is not available for its mission, it is just as useless as if it did not meet its performance requirements. "System readiness and sustainability are as important as system performance." (10:24)

Emphasis, therefore, is placed on meeting performance requirements without compromising logistic requirements. Often this becomes a very difficult task because increased complexity is often required in a weapon system to meet operational requirements and simplicity is the key for meeting logistical requirements. However, history shows that new weapon systems continue to become more complex. The technological complexity of new weapon systems is growing at an exponential rate. (18:112) This increasing complexity has had an impact on the ability of the Department of Defense to maintain these weapon systems. In fiscal year (FY) 1983, the Department of Defense (DOD) dedicated over 37% of its manpower and 15% of its budget to the maintenance of its weapon systems (15:III-162, IV-8,9). This represents a significant outlay of DOD resources.

The ultimate logistical goal is to eliminate the need for routine logistics support. The perfect aircraft would be delivered by a contractor, ready to perform its mission. From that point on it would require no logistical support. The fuel would be of a self-generating nature and would not require servicing. The weaponry, if it were not a transport aircraft, would be renewable, possible some sort of laser or particle beam weapon. The subsystems, such as avionics, engines, and so forth, would not fail but be perfectly reliable. Even the aircraft's landing gear would not be susceptible to wear, as contrasted with current tires and brakes. The crew could fly its mission and, immediately

upon landing, another crew could take off and fly another mission in the same aircraft without anything being done to it. The only repairs that would ever be required would be those due to battle damage, severe weather, aircraft accident, and the like.

Of course, this technology is not available to us yet. The next generation aircraft will not be logistically perfect, but some improvements over current aircraft must be made. How can we achieve these improvements in future aircraft? What do we want in 1990 or 2000? (6) The burden of support system requirements must be removed from operations but how should this be done? New approaches must be made to solve the logistical problems inherent in present day aircraft.

Purpose of the Study

This research will outline, in a broad perspective, the elements necessary for developing a logistically ideal aircraft. Some areas to be studied include acquisition, operational requirements, requirements determination, transportation, supply, maintainability, durability, and logistic supportability. The results of this research are expected to serve as a basis for further research when considering logistics issues throughout the life cycle of an aircraft. This research may be used as an aid to reducing the problem of trying to maintain increasingly complex systems.

Background

At any time Air Force aircraft may be deployed to tactical battle fronts anywhere in the world to protect United States interests. More frequently, flying units are deployed worldwide to show United States resolve through a show of force or to demonstrate a United States presence. Because current aircraft rely heavily on logistics support to perform their mission, operational commanders are burdened with a long logistics pipeline back to the United States for support of their aircraft. Another burden commanders experience is being required to bring along large numbers of maintenance and other support personnel and equipment to any base to which the unit is deployed. This compounds the problem of the initial deployment. Sufficient airlift must be dedicated to transport the required maintenance and support functions to the new operating location. If a number of flying units are being deployed simultaneously, there may not be sufficient airlift to support the deployments. This would result in a reduction in capability in the deployment area that could jeopardize the purpose of the mission.

The effectiveness of the unit is not just a function of the performance capability of the aircraft but is also a function of the amount of support required. An aircraft is useless when it sits on the ground being serviced. An aircraft may as well not be at the battle front if it is grounded waiting for a replacement hydraulic pump, or any

other replacement part, to be shipped from the United States. Reliance such as this tends to diminish the effectiveness of that aircraft. "They [aircraft] cannot require large amounts of support equipment and personnel for mission-critical subsystems, such as avionics and engines" (13:3). Aircraft critical to the defense of the United States should not be heavily dependent on logistics support. A reduction in logistics support requirements would increase the availability of an aircraft. "Ultimately, the limiting factor on what any military force can do depends on its logistics support" (11:2). Going beyond this, the limiting factor on what any military force can do is a function of its dependence upon logistics support.

Logistics considerations also heavily affect life cycle cost. Generally, attention is focused on the cost of buying a new weapon system, while life cycle cost, or the cost of buying and maintaining a weapon system over its expected life, is given less attention.

The need to address total system life cycle cost (in lieu of acquisition cost only) is evident, and experience has indicated that logistics support constitutes a major contribution to life cycle cost. (1:51)

Life cycle costing is an effective way of quantifying logistics supportability. Increasing life cycle cost indicates decreasing supportability. Recently, operating and support costs have grown so rapidly they now dominate as the major element in a system's total life cycle cost. (17:5)

Operating and support costs are the costs of operation, maintenance, and the follow on logistics support of the end item and its associated support systems. (16:107)

Unless additional emphasis is placed on life cycle costs during the development and acquisition phases of a new weapon system, operating and support costs will continue to dominate.

Logistics factors need more consideration in aircraft design and development. "Logistics considerations are often vague--even unrealistic. Logistics factors must be just as carefully identified and planned" (12:16). Poorly defined logistics design parameters cannot be translated into verifiable, achievable goals for the contractor. (9:70) Logistics planning should be done early, for decisions about the systems requirements made prior to full scale development have been found to determine approximately 85% of the total life cycle cost. (7:9)

A great deal of the impact on projected life cycle cost for a given system or product stems from decisions made during the early phases of product planning and conceptual design. Decisions made at this point have a major effect on operations in all subsequent phases of the life cycle. As logistics costs assume major proportions, it is essential that logistics support be considered at the early stages of system/product planning and design. (1:51)

Proper logistics planning would decrease the requirements for logistics support after the aircraft has been fielded operationally.

For the perfect logistics aircraft, life cycle cost would be the same as initial acquisition cost. There would be no support costs for this weapon system. A flying unit's effectiveness would be limited only by the number and qualification of the flight crews it has to fly the unit's available aircraft. For the next generation aircraft, life cycle cost must come closer to acquisition costs and dependence upon logistics support must be reduced.

Problem Statement

All aircraft developed by, or for, the military have some types of logistic problems. What are some of the specific items that should be considered in the planning of future aircraft to avoid the logistic problems of current aircraft? This research effort will not be an attempt to design an aircraft to solve logistic problems, but will describe one.

Research Questions

The following research questions were developed to support the overall objectives:

1. What are the logistic problem areas currently being encountered?
2. How could these problems have been avoided in the design or planning stage?
3. How can these solutions be fitted to a logistically ideal aircraft?

Summary

To summarize, the pertinent facts presented in this chapter include:

1. New aircraft acquisition results from the inability of older aircraft to adapt to a changing threat environment.
2. Logistics requirements are generally either too defined or are set aside to ensure the aircraft meets its performance requirements.
3. The resulting logistics support requirements inhibit the operational effectiveness of the aircraft and drive up its life cycle costs.

II. Methodology

Chapter Overview

The objective of this research was to identify the logistic problems of present day aircraft and identify possible solutions to use in describing a logistically ideal aircraft. A three-phase research plan was developed to accomplish this objective. The three phases included: (1) Identification of problems, (2) Identification of possible solutions, and, (3) Description of the logistically ideal aircraft.

In phases one and two, expert opinion was solicited to (a) identify logistical problems of present day aircraft which reduce the standards described in phase one and (b) identify possible solutions to those problems described in part (a). Phase three described the ideal aircraft from a purely logistical perspective.

Identification of Problems

The purpose of phase one was to identify logistical problems inherent in present day aircraft which reduce the logistic supportability of these aircraft. To accomplish this objective, experts were asked to discuss logistical problems they have experienced that pertain to aircraft acquisition. In addition, they were asked to discuss logistical problems they may have experienced in an operational environment. For this research, an expert was

an individual who had experience in the logistics field and had risen to a level, within their profession, that identifies them as a competent and qualified logistician. Due to the large number of candidates that could fit our definition of "expert", it was appropriate to sample rather than conduct a census of opinion.

The sample from the target population was representative of three general areas. First, senior Air Force logisticians representing practical experience in Air Force planning and operations; second, senior Air Force logisticians representing practical experience in headquarters operations and maintenance areas; and third, retired military logistics personnel representing a mix of planning, operations, and maintenance at all levels of Air Force activity. This method of sampling was expected to be representative of the target population.

Criteria was established in each general area for inclusion in the study. The senior Air Force logisticians representing experience in planning and operations were on active duty and serving in the grade of O-5, GS-14, or above. The senior Air Force logisticians representing major command headquarters were on active duty and serving in the grade of O-5, GS-14, or above. Finally, the third group qualifications were self explanatory. The sample was neither collectively exhaustive nor mutually exclusive. In addition, the sample may not have been representative of the

target population because a large amount of data was based on personal judgements which may vary from person to person.

The Delphi method was used to obtain expert opinion. The Delphi method, developed by the Rand Corporation, is a method of forecasting probable future events and trends, as well as solving theoretical problems. The name was taken from the oracle of Delphi in the Greek city-state of the same name. From the seventh century B.C. until the first century A.D., the oracle of Delphi was consulted by many to forecast what the future would bring. The Delphi methodology is explained later in this chapter.

The Delphi method was used in this research for two reasons. First, the experts could not all be located at a single location. Therefore, a meeting with all selected experts was not possible because of individual commitments and funding constraints. Second, the questions to be asked were theoretical in nature. Based on these constraints, the Delphi method was selected as the most appropriate method for collecting expert opinion.

Identification of Possible Solutions

The purpose of phase two was to identify possible solutions to the logistic problems discussed in phase one. This objective was accomplished using the Delphi method described later in the chapter. Experts were asked how the logistic problems previously identified could be corrected or avoided in the future. The experts used for this phase

were the same as those used for phase one. This phase was critically important for two reasons. First, the results of this phase were used to describe the ideal logistical aircraft. Once the logistical problems were identified, it was necessary to identify possible solutions for those problems. These solutions were based on the personal judgement of experts using the Delphi method.

Second, it helped validate the problems identified in phase one. Normally, when logistics problems occur, an attempt is made to identify the cause of the problem and some sort of action is taken to correct the problem. The corrective action may be permanent or temporary based on the magnitude of the problem, the amount of time available to correct the problem, or the funding available for correction of the identified problem. If the corrective action is permanent, no further action is taken and the problem is considered resolved. When the corrective action is temporary, some action is expected in the future to permanently solve that particular logistical problem.

These temporary actions were the areas this research attempted to identify because those actions did not result in resolved problems. Possible solutions to these types of problems were used in describing a logistically ideal aircraft. The permanent corrective actions were not used in this research effort.

Once possible solutions were identified and a consensus had been reached by the experts, the description of an ideal logistical aircraft began. Before discussing phase three of the research plan, it is appropriate to discuss the Delphi method in greater detail.

Delphi Method

Since mathematical models cannot be used to solve theoretical problems and questions, the Rand Corporation developed a method of soliciting expert opinion to answer questions of a theoretical nature. Dalkey described the Delphi method as follows (3:1):

Delphi is the name of a procedure for eliciting and refining the opinions of a group of people. In practice, the procedures would be used with a group of experts or especially knowledgeable individuals.

This method uses an iterative procedure to obtain a consensus from experts. Iterative feedback aids in developing a final consensus from the experts by allowing a free-flow of information among the experts and opportunity to rethink a question.

Experts are used in the Delphi method because of their extensive knowledge and experience concerning a particular subject area. One Rand researcher discussed the reason for using experts (2:13):

We use an expert because he has at his disposal a large store of background know-

ledge and a cultivated sensitivity to its relevance which permeates his intuitive insight. We need a consensus of experts because individual experts will disagree and are unwilling to rely on the judgement of a single specialist.

For this research, we defined an expert to be an individual experienced in the logistics field and who has risen to a level, within his profession, which identifies him as a competent and qualified logistician.

The Delphi method is not just a technique for simply generating opinions about a subject area. Respondents are also asked to give reasons for their expressed opinions and these reasons may be subjected to a critique by fellow respondents (2:3). The reason for an expressed opinion along with the critique of that opinion by fellow respondents is a major factor in reaching a consensus. As the opinions and critiques are reviewed and refined by all respondents, a consensus emerges.

For most subject areas, more than one iteration will be needed to reach a consensus. Past uses of the Delphi method have occasionally produced a consensus in as few as one iteration and rarely are more than three iterations needed. According to one Rand report, it is not uncommon for a consensus to be reached in two iterations (5:5). It was expected that two iterations would be needed to reach a consensus for this research effort. The first iteration commenced when the selected experts were sent a questionnaire. The experts were asked to complete the

questionnaire and provide supportive rationale for their opinions. The second iteration provided feedback to their original responses and requested critiques, comments, or explanations from fellow respondents. This feedback allowed each respondent to modify their response or continue with their previous response. The respondents provided additional support for their opinions. This procedure was repeated until a consensus was reached.

Consensus Criteria

A consensus was to be achieved when more than sixty percent of the respondents agreed on a topic area. The sixty percent was based upon the actual number of active participants and not the number of experts originally selected to participate. Sixty percent was selected because that represents a three-fifths majority on that particular topic area. It was expected that several topic areas were identified in the questionnaire distributed to the experts. Those topic areas not achieving a sixty percent consensus were considered "no consensus reached" topics. The criteria for terminating the iterations was when at least fifty percent of the topic areas identified in the original questionnaire reached consensus.

Questionnaire

The Delphi questionnaire was compiled so there would be no leading questions. The spontaneity of expert opinion was

expected to come from open questions. Also, the length of the questionnaire was designed to require no more than one hour to complete. To validate the questionnaire against both of these requirements, the questionnaire was submitted to logistic instructors at the School of Systems and Logistics, Air Force Institute of Technology. The results of the pretest were incorporated into developing the first round questionnaire.

Rules for administering the Delphi questionnaire and the first round questionnaire are contained in appendix A.

Advantages of Delphi

The Delphi method has several significant advantages. First, the negative effects of group interaction is eliminated. A Rand research report states (3:2-3):

Delphi reduces undainted aspects of group interaction (i.e. dominance of an individual, group pressure, etc.) . . . by anonymity, controlled feedback, and statistical "group response.

The report explains how anonymity, controlled feedback, and statistical "group response" aid in reducing the negative effects of group interaction. Anonymity is a device to reduce the effect of the socially dominant individual (3:3). A dominant personality in a group can influence the decision of others in the group. In a military setting, such as the panel of experts used for this research, rank could play a role to influence another person's decision. Anonymity eliminates these effects. Controlled feedback reduces

noise, that is, irrelevant or redundant material which obscures the directly relevant material offered by participants (3:3). The feedback provided to the experts is filtered, using the Delphi method, and contains only pertinent, constructive information. This aids in surfacing only the necessary information needed to reach a consensus and suppressing any redundant or irrelevant comments. Statistical "group response" helps reduce the group pressure to conform which is present in face-to-face discussions (3:3). In many group meetings, there is some pressure to agree with stated responses instead of criticizing them. This effect is drastically reduced using the Delphi method.

A second advantage of the Delphi method is the elimination of scheduling problems. Finding a convenient time for all selected experts to meet at a selected site could be extremely difficult. Using the Delphi method, the questionnaire is sent to the participants and they complete the questionnaire when it is convenient for them. No meetings are required.

Third, the participants can complete the questionnaire at their leisure and wherever they feel comfortable. This may enhance their responses when compared to meeting in a group, at a set hour, and in an unfamiliar location.

Finally, the final consensus is at least as good as the result of a committee (4:1). Research has shown that the Delphi method will produce results that are the same, or

better, than a committee. However, as described above, many negative effects of group meetings are avoided or reduced using the Delphi method.

Arguments Against the Delphi Method

The basic argument against the Delphi method is that it violates basic scientific research requirements.

Analysis of the conventional Delphi indicates it does not satisfactorily meet the numerous experimental and methodological standards cited for test design, item analysis, subject sampling, reliability, validity, administration, interpretation of findings, and warranted social use (14:v).

It appears the scientific research philosophers have not embraced the Delphi method as a valid means of conducting scientific research. However, since the Delphi method is used to obtain a consensus about theoretical concepts, not readily measured by quantitative techniques currently available, it is appropriate to use for this research effort.

Summary of the Delphi Method

The Delphi method was developed by the Rand Corporation as a means to solicit expert opinion for answering questions of a theoretical nature. The Delphi method uses iterative feedback to achieve a consensus of expert opinion. Experts are used because of their extensive knowledge and experience about some particular subject area. Although the Delphi has not been fully accepted by scientific researchers, it has

the advantage of producing as good as, or better results than, a committee, while reducing the negative effects of group interaction.

Description of the Ideal Logistical Aircraft

The purpose of phase three of the research plan is to describe an ideal logistical aircraft based on results from the Delphi method employed in phases one and two. The Delphi method will identify logistics problems with present day aircraft and possible solutions to those problems. That information will be used to describe the elements which will be included in the ideal logistical aircraft.

Summary

This chapter has outlined a three phase research plan which was used for this research effort. The three phases included: Identification of Problems; Identification of Possible Solutions; and Description of the Ideal Logistical Aircraft. Phases one and two used the Delphi method to reach a consensus on what problems currently exist with present day aircraft and possible solutions for correcting those problems. The Delphi method was discussed in detail. Phase three discussed how the ideal logistical aircraft was to be described using the information obtained from the first two phases.

III. Findings

Chapter 2 detailed the research plan used for this research project. The plan involved three phases, which included: Identification of Problems; Identification of Possible Solutions; and Description of an Ideal Logistical Aircraft. This chapter will discuss the results of each phase discussed in the research plan.

As detailed in chapter 2, the purpose of phase one, identification of problems, was to identify logistical problems inherent in present day aircraft which reduce the logistic supportability of those aircraft. The purpose of phase two, identification of possible solutions, was to identify remedies to correct any inherent problems identified in phase one. The Delphi method was used to accomplish this objective. Discussion of round one of the Delphi method is discussed below.

Round One of the Delphi Method

A total of 26 questionnaires were sent out for round one. Of those 26 mailed to selected respondents, 10 returns were received for a 38% response rate. The questionnaire used for round one can be found at appendix A. The following is a discussion of each question as received from those responding to this round:

1. **AIRCRAFT SUBSYSTEMS:** An aircraft consists of many subsystems (ex. airframe, engines, etc). List and rank order what you consider to be the top five subsystems as sources of logistic problems (Number one being the subsystem with the most logistic problems). Please explain your choices briefly.

Numerous subsystems were identified by the ten respondents as being sources of logistic problems. However, eighty percent agreed that avionics was a major problem area. One respondent said current systems are demanding more and more tasks to be accomplished. With these additional tasks come increased sophistication and parts that have an opportunity to fail. For example, even with a reliability factor of .999, a subsystem that contains 50,000 parts can lead to a totally unacceptable subsystem reliability factor.

Fifty percent agreed that engines were a major source of logistic problems. Engines require operation at extremely high temperatures and tend to be very complex due to the requirements the engines must meet. Numerous component parts make an engine and these parts are subject to high failure rates. When failures occur, traditionally, the engine experiences a long downtime for repair and is very costly to maintain.

Other subsystems agreed upon by more than twenty percent of the respondents were hydraulics, landing gear, airframe, electric/power, fuel systems, flight control, fire control, and propulsion.

2. **AIRCRAFT COMPONENTS:** Identify and rank order what you consider to be the top five aircraft components that cause logistics problems. Please briefly explain your choices.

Numerous components were identified as causing logistics problems. Fifty percent agreed that those components involving a black box/LRU (line replaceable unit) caused the most problems. Many operational units are experiencing modular circuit board and on-board mini computer component shortages. To further the problem, significant amounts of time are spent by personnel trying to isolate faults. These problems result in increased maintenance time in terms of time to repair. In addition, high false alarm rates occur often and these cause unnecessary maintenance actions. This large number of problems cause maintenance units to work harder but often not necessarily smarter because maintenance problems must be identified and corrected as quickly as possible. One respondent said greater emphasis must be applied to maintainability and function of an aircraft or system, rather than who's turn it is to get a contract. More attention in this area would result in a better product and probably decrease maintenance nightmares significantly.

Other components identified by at least twenty percent of the respondents include: hydraulics, pneudraulics, fuel system components, radar, actuators, electronic components, fuel controls, connectors, avionics, and landing gear. One individual indicated that these problems would vary from

aircraft to aircraft and to generalize would not be appropriate.

3. LOGISTIC AREAS: Logistics covers four main areas: supply, transportation, maintenance, and procurement. Please rank order these from the most to the least problems and briefly describe the major problems and why they exist.

Fifty percent of those individuals responding to this question do not believe logistics simply covers these four areas. Other areas of equal importance include: requirements determination, design data base, and computer aided design/computer aided manufacturing. However, all these other areas could be considered in part as a portion of the four areas detailed in the question.

As for the four areas identified in the questionnaire: supply, transportation, maintenance, and procurement; maintenance was most often identified as having the most problems from a logistics standpoint. One respondent said maintenance includes over twenty-nine percent of the total enlisted force. It includes over forty-two separate career fields and is compounded by more than fifty aircraft or system shred outs. A shred out is that portion of the Air Force Speciality Code which identifies a specific area of expertise. The problem is further complicated by the fact that most operational units have inadequate test equipment and poor diagnostics with which to perform their jobs. Training is often not sufficient at technical training schools. By this the respondents mean the training is not

sufficient to allow a new graduate to work directly on the aircraft without supervision upon arriving at a new duty station because, often, aircraft have had some modifications in its hardware or software that the training school is not aware of. In addition, permanent change of station assignments occur much too frequently, retention of first term airmen is not adequate when compared to the amount of time these airmen spend attending schools and, finally, productivity is often low. Compounding these problems are mission statements that are changed for the weapon systems. When these changes occur, maintenance must identify new procedures to meet the changing requirements. The identification of these new procedures and then the implementation of the plans for new procedures often take the maintenance personnel away from their jobs of repairing aircraft to the job of being a planner. Maintenance personnel are finding themselves managing facts and figures of their operation and not the aircraft.

4. FACILITY PROBLEMS: Identify and rank order the top five facility problems you perceive with respect to aircraft logistics and briefly explain why.

This question was not directly aimed at achieving a consensus but, rather, to obtain a variety of opinion and thought concerning facilities and some current problems. Lack of hanger space, inadequate warehousing and shelters for computer equipment, poor washing facilities for aircraft, problems with real property installed equipment

and, generally, a severe lack of military construction project funds to modernize outdated facilities were some of the problems identified by respondents.

A trend in problem areas for facilities that most respondents identified had to do with facilities being outdated. Several individuals said that maintenance shops are of a World War II design and are not functionally laid out. Inadequate storage space is a common problem because as these areas expanded over the years, storage space slowly diminished until, today, far too little space is available. Since the shops are not functionally laid out, the production effort is severely hampered. Additional military construction project funding should be made available to revamp these outdated facilities, according to several respondents. The cost would be more than offset by the savings that could be realized by a more efficient layout and design.

5. **GROUND SUPPORT:** Identify and rank order what you perceive to be the top five aircraft ground support equipment problems and briefly explain why.

As with the previous question, this issue of ground support was included to obtain a variety of opinion on the subject matter. Some problem areas identified were automated ground equipment, acquisition of support equipment for new weapon systems, nonavailability of spare parts for new and old equipment, munitions handling equipment, too much reliance on fuel trucks for refueling, too much

diversification of ground support equipment which results in low reliability, and skyrocketing costs for ground support equipment.

6. **DIAGNOSTIC CAPABILITY:** Are some aircraft subsystems harder to troubleshoot than others? If so, identify and rank order the top five subsystems that have diagnostic capability problems and briefly explain why.

There was a consensus that some subsystems are harder to troubleshoot than others. Seventy percent of the respondents listed problem areas. Twenty percent of the respondents did not believe this was true but was rather a function of the experience of the mechanic. The remaining ten percent were of no opinion.

The subsystems listed by the consensus group were compiled based on frequency of appearance and rank order. Avionics was listed by forty-three percent of the positive respondents. Avionics are affected by their sensitivity to adverse conditions and inadequate test and diagnostic equipment. These systems have long troubleshooting and repair times. However, great improvements are being made in newer generation aircraft. Engine/bleed air was also listed by forty-three percent of the respondents. Twenty-nine percent stated that radar and electrical systems were problem areas; radar by virtue of the vast number of individual parts that may fail. The remaining subsystems, electronic warfare, instrumentation, communications, flight controls, and environmental systems were each listed once.

7. **TRAINING:** Do you consider the average aircraft maintenance person to be sufficiently trained and capable to accomplish their mission? Explain.

There was no consensus on this question in the first round. Thirty-three percent of the respondents agreed that the average maintenance person is sufficiently trained to accomplish his or her mission. Fifty-six percent of the respondents felt maintenance personnel do not receive sufficient training. Eleven percent believed it was a function of the skill area.

Those who agreed with the question felt that, overall, the average maintenance person is sufficiently trained. They also felt an aggressive on-the-job (OJT) training program is required. Even though training is sufficient, there is still a lag in personnel competence when a new weapon system is introduced.

The respondents who disagreed believed that all maintenance personnel should be trained as airplane general (APG) mechanics first. Then, after their first reenlistment, they can be specialized as necessary. Currently, according to one respondent, personnel are only trained enough in the technical schools to be dangerous and then they are turned loose on the flight line with insufficient supervision. To improve this situation, there should be an automated engineering data base to lead technicians in step-by-step repair. This would lead to the elimination of Field Training Detachments (FTD).

Another problem with current training levels is that the maintenance field has too many first term airmen relative to the total maintenance force. To overcome this inexperience, non-commissioned officers (NCO's) need to be retrained and retrained in actual maintenance performance duties.

B. MAINTENANCE PERSONNEL: Should aircraft be designed so that flight line maintenance personnel should be specialists or generalists? Explain.

A consensus of the respondents was that flight line maintenance personnel should be generalists. Eighty percent responded in this manner, while ten percent were of the opinion that maintenance personnel should be specialists. Ten percent had no opinion.

The respondent in favor of specialists believed that a maintenance person should start as a specialist. Then, as the individual's grade and experience increase he should be broadened to a generalist.

The consensus respondents believe there are too many under-utilized specialists now and that this current specialist structure is a burden to wartime commanders. Generalists could better support wartime dispersals but a few back-up specialists may be needed, given the complexity of today's weapons systems. A broader area of maintenance knowledge would also be helpful in handling the peaks and valleys of the maintenance workload. Aircraft should be

designed so that APG's can handle all on-equipment maintenance. Specialists should handle off-equipment maintenance in field repair facilities and depots. This would, in the opinion of one respondent, cut Air Force maintenance manpower requirements by at least fifty percent.

9. LOGISTICALLY IDEAL AIRCRAFT: What thoughts would you employ if you were assigned the task to describe the logistically ideal aircraft?

All respondents enumerated their considerations with respect to designing a logistically ideal aircraft. This question was not aimed at a consensus, but at obtaining an array of diverse thoughts. In spite of this, there were common areas mentioned by many of the respondents. Seventy percent indicated they would require a high system Mean Time Between Failure (MTBF). Fifty percent would have all critical test points exposed and accessible. Forty percent would require the aircraft to have a high self-diagnostic capability.

The remaining thoughts were more diverse. All Line Replaceable Units (LRU) should be accessible. The database for the aircraft should support generalist maintenance skills, not require specialists. The system should have a low Mean Time to Repair (MTTR). Simplicity should be the key to the aircraft design. There should be a fully designed maintenance bay in which every aspect of the aircraft can be tested and maintained. Wire bundles should be in segments so that they become Line Replaceable Units.

No ground support equipment should be needed. Only common tools would be required, not specialist tooling. The aircraft should use as many "throw away" parts and components as can be economically and safely used. Last, the aircraft should be constructed of corrosion proof materials.

10. BATTLE DAMAGE: What design features should be incorporated in an aircraft to increase immediate repair capability for battle damage?

As with the previous question, this question was included to elicit a variety of thoughts, not a consensus. The responses to this question were varied. Aircraft modularity was cited as a means of increasing battle damage repair capability. An airframe that could be broken into modules could be repaired rapidly. Critical subsystems and components should be redundant and be located on opposite sides of the aircraft for survivability. The fuel cells should be self-sealing. The aircraft should be designed with a knowledge of what materials would be available with which to make repairs during a war time scenario. Easy access to subsystems would be required for speedy repair. Composites should be developed that are as "workable" as sheet metal. Credible repairs must be developed for canopies. Flight controls must have a self-repairing capability. Electrical bundles must be well defined and identified. There should be an integration of common functions between avionics systems, i.e., a generic computer

to satisfy the computing needs of all the subsystems. The aircraft should be designed with a graceful failure of the subsystems. Although some of these were listed by more than one respondent, none were listed by more than half of the respondents.

Round Two of the Delphi Method

A total of 26 questionnaires were sent out to respondents for round two. Although only ten responses were received for the round one questionnaires, it was believed some respondents might respond to the second round questionnaire. Therefore, questionnaires were sent to all respondents identified for participating in the Delphi method for this research. In addition to the round two questionnaire, if the respondent participated in the first round, their first round response was also included in the round two package. Of those 26 mailed to the respondents, 15 returns were received for a 58% response rate. The questionnaire used for round two can be found at appendix B. The following is a discussion of each question as received from those responding to this round:

1. **AIRCRAFT SUBSYSTEMS:** An aircraft consists of many subsystems (ex. airframe, engines, etc). List and rank order what you consider to be the top five subsystems as sources of logistic problems (Number one being the subsystem with the most logistic problems). Please explain your choices briefly.

A consensus was reached in round one that avionics was a major problem area for aircraft subsystems. In round two, eighty-six percent of the respondents agreed that avionics and engines were major problem areas. In addition fifty percent agreed that fuel systems were a major problem area.

Forty-three percent of the respondents identified hydraulics as being a problem area, while thirty-six percent of the respondents said electrical power systems and air frame subsystems were major problem areas. Finally, twenty-nine percent agreed that flight controls and landing gears were major problem areas. Other subsystems were identified but by only one or two respondents. One respondent had no opinion to this question.

2. AIRCRAFT COMPONENTS: Identify and rank order what you consider to be the top five aircraft components that cause logistics problems. Please briefly explain your choices.

As with the first round responses, many aircraft components were listed as being the source of the most logistics problems. No consensus was reached in the first round as to which component(s) caused the most logistic problems and the second round responses also did not produce a consensus. One respondent said there were so many component problems on present day aircraft he could not break them down into which ones caused the most problems.

Fifty-seven percent of the respondents identified line replaceable units (LRU's) as being the cause of the most

logistics problems, at least from a component stand-point. Fifty percent of the respondents said fuel systems and hydraulics were the components that caused major logistics problems. Thirty-six percent identified radar components and twenty-nine percent identified connectors, landing gear, and avionics components as being major contributors to the logistics problems with components.

3. LOGISTIC AREAS: Logistics covers four main areas: supply, transportation, maintenance, and procurement. Please rank order these from the most to the least problems and briefly describe the major problems and why they exist.

A consensus was reached in round two for this question. Sixty-four percent of the respondents said that logistics could not be covered in simply these four areas: supply, transportation, maintenance, and procurement. Other areas identified were research and development design, manufacturing, deployment and support, computer aided design and computer aided manufacturing, to name a few.

Of the respondents that rank ordered the four identified areas in the questionnaire, maintenance was listed as the area with the most problems. One respondent said the ultimate user of all the material and services provided by supply, procurement, and transportation is maintenance. Sixty-four percent identified maintenance as the most significant area for logistic problems, of the four identified in the questionnaire. Procurement was listed as the greatest problem area by thirty-six percent of the

respondents. Eighty percent of the respondents said transportation posed the least amount of problems for logistics.

4. **DIAGNOSTIC CAPABILITY:** Are some aircraft subsystems harder to troubleshoot than others? If so, identify and rank order the top five subsystems that have diagnostic capability problems and briefly explain why.

On the first round, a consensus was reached that some subsystems were harder to diagnose problems in than others. There was no consensus, on the first round, on which subsystems, if any, were the most difficult to substitute.

The second round responses yielded a consensus on subsystems. Avionics was listed by seventy-seven percent of the respondents as the most difficult subsystem to diagnose problems. Electrical subsystems were listed by fifty-four percent of the respondents, followed by engines with forty-six percent, and radar and electronic warfare subsystems, each with thirty-eight percent. Of these top five problem subsystems, avionics is the only area with a consensus determining it as a particular subsystem that is difficult to troubleshoot problems.

5. **TRAINING:** Do you consider the average aircraft maintenance person to be sufficiently trained and capable to accomplish their mission? Explain.

A consensus was not reached on this question for round two. Fifty percent of the respondents agreed that the average maintenance person was insufficiently trained to

accomplish his mission, while fifty percent indicated the average maintenance person is sufficiently trained.

Those who responded negatively gave various reasons for their answers. Training should be done to Federal Aviation Agency (FAA) qualification status. Individuals should be generically trained across all systems. There is not enough training in software maintenance. There are too many diversions after training. People are not put right to work to practice what they learned. Maintenance manuals are not up to date. Individuals are trained enough to be dangerous and then turned loose on the flightline with insufficient supervision. There should be an automated engineering data base to lead the technician step-by-step in repairing. Information in this form is the avenue to massive skill compression and quantum increases in productivity. The whole training process needs to be reassessed. Air Force Logistics Command (AFLC), not Air Training Command (ATC), should determine training levels and requirements for they know how to support a system. Maintenance is overly weighted toward first term airmen. We need retention of experienced non-commissioned officers (NCO's) on the flightline.

Those who agreed that the average maintenance person is sufficiently trained, did so for several reasons. Overall initial training is sufficient but an aggressive on-the-job training (OJT) program is required. Nobody can be expected

to come out of an initial training program as an expert. Personnel in grades E1 (airman basic) through E4 (sergeant) are in the process of acquiring experience and knowledge. Most of their training, to this point, has been directed toward generalities. When an individual is identified for a particular weapon system, training should begin as soon as possible. A specific Field Training Detachment (FTD) should be added for this purpose.

6. MAINTENANCE PERSONNEL: Should aircraft be designed so that flight line maintenance personnel should be specialists or generalists? Explain.

The overwhelming response was that maintenance personnel should be trained to be generalists and aircraft designed toward this goal. Ninety-two percent responded in this fashion. The respondents stated that the equipment should be designed so the maintenance person does not have to go deep into the system to troubleshoot and repair. Maintenance flexibility will be increased, as will survivability. Airplane general (APG) mechanics should handle all on-equipment maintenance, with specialists handling off-equipment repairs in field repair facilities and depots. The crew chief should be able to troubleshoot all but the most complex systems. He should be a generalist across the many subsystems but a specialist to a particular aircraft type. We cannot afford the current under-utilized structure of specialists. This is a burden to the wartime commanders.

7. COMPLEXITY: Should we have many simple, inexpensive limited capability aircraft or a few, complex, expensive, multipurpose aircraft? Explain.

A consensus of respondents disagreed with the question as stated. Sixty-one percent stated that complexity does not exclude a simple and inexpensive design. Thirty-one percent felt that simplicity would increase operational capability. Eight percent had no opinion on this question.

Those that favored simple, inexpensive aircraft stated that aircraft should be designed for a single mission. Multi-purpose aircraft tend to do many things, but none of them well. The United States does a terrible job of funding maintenance on the aircraft it possesses now. There is little sense in having a few, complex aircraft you cannot afford to keep in working condition. Fewer aircraft would greatly reduce the amount of manpower required to support them but each aircraft loss would greatly limit our capability. Aircraft should be ruggedly designed and easily maintained, not a multipurpose aircraft, easily wounded and hard to support.

Those who disagreed with the question as stated felt that complexity does not necessarily exclude simplicity or imply expense. The weapon system must be designed so that complex technology is transparent to the high school graduate who will maintain the system. Complexity does not imply high cost of ownership. It may well involve high initial acquisition costs, but not necessarily high life cycle

costs. Simplicity of trouble shooting and repair does not imply that the aircraft is of limited capability. The threat drives the need. The weapon system must meet this threat. The technology required to meet the threat must be designed for supportability.

8. DESIGN: Should an aircraft be designed with the idea of pilot performed maintenance in mind? Explain.

A consensus of respondents believed that an aircraft should not be designed with the idea of pilot performed maintenance. Seventy-seven percent felt the pilot duties were too demanding already. Fifteen percent felt it depended on the situation. Eight percent had no opinion for this question.

The respondents who felt it depended on the situation believed certain scenarios could require pilot performed maintenance. Even in these special cases, flight crew maintenance should be limited to removing and replacing Line Replaceable Units (LRU). Any repairs beyond this level should be accomplished by maintenance personnel.

Most of the respondents felt pilot performed maintenance is impractical. The pilot has enough to do already. To keep himself ready to perform his mission, he must constantly study his flight manuals, weapons manuals, tactics, regulations, and procedures. To increase this load by requiring study and training in aircraft maintenance procedures would jeopardize his proficiency in his primary

mission. The pilot's duties in current high performance aircraft are demanding enough. Aircraft should be designed with self-diagnostic functions. The pilot could then be informed by this system where a fault or malfunction is. The pilot would be able to switch to back-up systems and fix the fault. This is the extent to which the pilot should perform maintenance. The task saturation in combat aircraft is such that we can not afford to overload the flight crew with additional duties.

9. FUTURE SERVICE: The number of teenagers eligible for military service is predicted to decline by 24% over the next two decades. Will this impact the role of logistic supportability for aircraft? If so, what should be considered in aircraft design to overcome this problem?

Seventy-one percent of the respondents agreed that a decline in the number of teenagers available for military service during the next decade would not have an impact on the role of logistic supportability for aircraft. Twenty percent said the decline would have an impact and one individual had no opinion for this question.

Many respondents said the Air Force will compensate for the lack of personnel (teenagers) coming into the military over the next twenty years by increasing dependence on remove and replace items for maintenance. In addition, self diagnostic/fault isolation systems will be increasingly used which will increase the serviceability of aircraft. One respondent said the Air Force is presently working to remedy

any shortage in new military personnel for the next twenty years. Possible solutions are being discussed at high levels within the Department of the Air Force. Some alternatives being discussed are contracting out maintenance and civilianizing more of the logistics functions. The amount of paperwork generated by maintenance in the past may be reduced in the future through the use of computers at the worksites. In addition, improvements in aircraft design should help alleviate some of the problem.

On the other side, continuous low reliability systems, subsystems, and components will require the Air Force to expend vast resources to have people maintain systems. In addition, as supervisors come off the flight line to work the "paper" problems of the organization, it is leaving, often, inexperienced and insufficiently trained personnel out on the flight line to perform maintenance actions. This is ineffective and inefficient.

10. ATE: Identify the major advantages and disadvantages of increased use of Automated Test Equipment (ATE) at the different levels of Air Force maintenance.

All but one respondent provided opinions of the major advantages and disadvantages of the increased use of Automated Test Equipment in recent years. One respondent felt this area was not one in which he could comment. About as many advantages as disadvantages were cited by respondents to this question.

Some of the advantages cited by the respondents include: the software used for the Automated Test Equipment allows testing to specific preset and predetermined tolerances; it will isolate faults; after the repair is completed it will perform confidence checks to assure the problem has been corrected. This advantage can be readily seen in the speed a problem can be isolated. Prior to ATE, it could take hours, sometimes days, to determine what the exact cause of a malfunction was. ATE can reduce that fault isolation time significantly and then, once repaired, assure the maintenance personnel the problem has been corrected. In addition, ATE allows many functions to be tested on a single line replaceable unit (LRU). This, again, is an advantage over the manual method of testing.

One respondent said ATE is the only affordable way to diagnose problems that occur in the complex circuitry of today's aircraft at any level of maintenance. With the complexity of aircraft increasing, maintenance personnel would have a very difficult time trying to find the actual cause of many of the problems that might occur with complex circuitry. ATE is the only cost effective way to perform these maintenance checks. But that is not to say ATE is an inexpensive method of testing. The high cost of ATE will be discussed shortly.

ATE allows for a more in-depth testing procedure as compared to a manual method. You could then assume that

problems that might go uncorrected by the manual method of testing will be found by ATE. This is true to a certain extent. ATE also allows for reduced set-up time for maintenance personnel and performs repetitive testing much easier than humans. As a result, ATE requires little operator interface after the initial set-up of the test equipment.

A final benefit to the use of ATE is that fewer maintenance personnel are needed to perform the maintenance testing function on those weapon systems that utilize ATE. However, in many cases, more maintenance personnel are often needed to maintain the test equipment. In addition, those maintaining the test equipment must be more specialized. In the long run, for present day systems, a reduction in maintenance personnel has not occurred overall. The emphasis and specialty of the maintenance personnel have changed.

Some of the disadvantages of ATE include a high cost to operate. Often the ATE is extremely complex, even in terms of the weapon system it is supporting. This complexity rears its ugly face to the maintenance personnel trying to maintain the equipment. The complexity also manifests itself with a high false alarm rate. This adds to the cost, indirectly, by increased manhours performing fault isolation checks which often turn up no significant problems. The high false alarm rates reduce the confidence maintenance

personnel place in this complex automated test equipment. Costs are also high to train personnel to operate, maintain, and develop the test equipment. As was mentioned, the ATE usually has a very complex design and training is extensive. To complicate that problem further, a standardized ATE for use on all weapon systems has not been developed so personnel are faced with having to learn about the test equipment all over when they transfer to a new base and a new weapon system.

The ATE is not charitably responsive to changes in environmental requirements or general performance requirements. With the complex circuitry of ATE, changes in humidity, temperature, altitude, etc. have a significant effect on the operation of the test equipment. The software used for ATE is also not easily changed to meet changing operational requirements which often result as a weapon system progresses through its life cycle.

Finally, the ATE is often fragile and the increased size and weight of the weapon system that carries the ATE aboard the aircraft can, in some cases, affect the weapon systems transportability. This problem can produce significant performance degradation.

IV. Analysis

This research was the first attempting to discuss those areas that would be important in developing a logistically ideal aircraft. Current aircraft rely quite heavily on logistics support to perform their assigned missions. In fact, aircraft today spend more time having logistics functions performed on them than they can spend in the air actually carrying out their missions.

To complicate this problem, life cycle costs have skyrocketed in the past decade primarily due to operating and support costs growing at such a fast rate. With life cycle cost rising so rapidly, along with the technical complexity of aircraft increasing at an equally rapid rate, it does not seem likely that costs will reduce in the near future unless a different course of action is taken.

That new course could be in the form of a greater emphasis on logistics factors in the design and development stages of aircraft acquisition. If logistics planning was accomplished earlier in the acquisition cycle, the requirements for logistic support after the aircraft has been fielded would drop significantly.

The objective of this research was to outline the elements necessary for developing a logistically ideal aircraft. This aircraft would, ideally, require no additional support once it has been fielded. To accomplish this objective, a three phase research plan was used. In

phase one, some of the logistical problems inherent in present day aircraft were identified. These logistical problems have the effect of reducing logistic supportability in the long-run. Phase two identified possible solutions to those logistic problems that were identified in phase one. Finally, in phase three, some of the elements of a logistically ideal aircraft were presented.

Discussion

There are several significant logistical problem areas currently being encountered. These problem areas are in aircraft subsystems, maintenance, facilities, and support equipment.

Aircraft avionics are major problem areas in current aircraft. Avionics are affected by their sensitivity to adverse conditions. The number of parts in the subassemblies are increasing with the sophistication. Even a high component reliability factor cannot prevent an unacceptable system reliability factor. These subsystems have been plagued by high false alarm rates. The high number of components makes avionics problems difficult to troubleshoot. Avionic subsystems problems are difficult to diagnose and it is time consuming to isolate faults. A part of this problem is due to inadequate test equipment and diagnostic equipment. These problems combine to increase the maintenance repair time required by this subsystem.

Another aircraft subsystem that characteristically causes logistical problems is aircraft engines. Increasing performance and mission requirements have increased the complexity of aircraft engines. They must perform under a variety of adverse conditions. Many of the components are subjected to extremely high temperatures. As a result, engines components are subject to high failure rates. Once a failure occurs, the engine experiences a long maintenance down time to repair it.

Maintenance is one of the four main logistics areas that also includes supply, transportation, and procurement. It is a logistics problem area. The current maintenance career field in the Air Force has too many specialists. These specialists are under-utilized and, in wartime scenarios, are a burden to tactical commanders. Generalists could better support wartime dispersal scenarios. Maintenance units do not have adequate test equipment and diagnostic equipment to properly perform their jobs. Permanent change of station (PCS) assignments occur much too frequently. An individual begins to feel comfortable in his location and unit when he must move. Retention of first term airmen is poor, which generates the requirement for new personnel in junior grades who must attend the appropriate technical training schools. This is an additional requirement that should be eliminated by increasing retention.

There are many facility problems that create logistical problems. These include the lack of hangar space, inadequate warehousing and shelters for computer equipment, and poor washing facilities for aircraft, among others. The predominant and most severe problem area is that many facilities are outdated. Maintenance shops are of World War II vintage. The layout is not functional and there is little storage space. As maintenance shops expanded over the years, storage areas were converted into work areas. Now, there is too little space. Production efficiency is inhibited by the disfunctional, ad hoc layout of the shops. Facilities suffer from a shortage of funds to bring them up to date.

Ground support equipment can also cause a multitude of logistical problems. Some of the major problems with ground support equipment stem from the acquisition process. Standardization is one of the main problems. Often we have, for various aircraft, many different types of equipment designed to do similar things. Much of this problem comes from support equipment requirements not being properly screened to determine if there is usable common support equipment already in the Air Force inventory. Support equipment managers are often not involved in the acquisition of new weapon systems. Likewise, new or replaced support equipment is entering the Air Force inventory without the benefit of user participation during preplanning, testing,

and technical order verification phases of procurement. Another problem arises because often no training is provided by the contractor prior to receipt of new support equipment into the Air Force inventory. These problems result in support equipment not having high reliability initially and often leads to rapidly rising costs during the life cycle.

Logistically Ideal Aircraft

These problems identified combine to reduce the effectiveness and increase the life cycle cost of current aircraft. A logistically ideal aircraft would have none of these problems. It would not have logistics support requirements at all, except for battle damage or aircraft accident repair. A description of this type of aircraft was not achieved for this research. The scope of the responses to the questionnaires was restricted to current, achievable technologies and did not attempt to forecast possibilities of the future. The result is a description of an aircraft that would eliminate the problems that plague current aircraft. The approach to the logistically ideal aircraft that results from this research still requires ground servicing prior to flight and is subject to normal wear and tear. This logistically ideal aircraft moves to eliminate current logistics support problems discussed earlier but not all logistics support requirements.

There are many features this logistically ideal aircraft would incorporate. The aircraft must have a high system mean time between failure (MTBF). High reliability of individual components does not guarantee this because of the large number of components in many subsystems. If common functions of avionics subsystems were integrated, the number of specialized components could be reduced and redundancy included in the generic components. For example, do not incorporate an individual, dedicated computer for each avionics subsystem. Instead, have a generic central computer which would satisfy the computing needs of all the subsystems. This would significantly reduce the number of components in each of the subsystems, possibly enough to create room for a redundant, back-up generic computer in the same space previously occupied by all the avionics subsystems' dedicated computers. This redundancy would increase overall system reliability. Survivability would also be enhanced by selected system redundancy, especially if the redundant systems were located on opposite sides of the aircraft. Then combat damage would be less likely to destroy the aircraft's subsystems and render further flight impossible.

All of these subsystems, when they fail, must be accessible for repair. They should be built in the form of Line Replaceable Units (LRU). LRU's must be accessible from the ground or cockpit without having to move equipment out

of the way. The generic computer should have diagnostic capabilities to identify failed or failing LRU's. This would reduce fault isolation time considerably over many current aircraft. If this were incorporated with highly accessible LRU's, the mean time to repair (MTTR) of the aircraft would be low.

Current aircraft have, literally, miles of wire in them. When there is a wiring problem many manhours are expended tracing and identifying the proper wire in the proper bundle. The logistical ideal aircraft would have wires and bundles well defined and identified. In addition, the wire bundles would themselves be segmented into LRU's. This would decrease MTTR of the aircraft since, when a wire problem is indicated, the bundle can be quickly pulled and replaced to return the aircraft to operational capability.

The logistically ideal aircraft would have a fully designed and functional maintenance bay capable of returning an aircraft to mission ready status. This bay would include test and diagnostic equipment to supplement the aircraft's on-board self-diagnostics. All critical test points for the aircraft would be exposed and accessible from the ground. This would help to lower maintenance down time on the aircraft.

Construction should be of corrosion proof materials. The advantage of this is obvious. Composites satisfy this but current composites are difficult to work with. Repairs

are costly and time consuming. Composites should be developed that are as easy to repair as sheet metal. This would ease repair problems considerably while eliminating corrosion.

The aircraft's design should be modular. For example, if the airframe could be broken in modules, repair time would be reduced and the maintenance load eased.

Self-sealing fuel cells would be incorporated. Fuel cell leaks have been a time consuming item to repair which involved draining the tank, resealing, allowing the seal to cure, and testing. Resealable cells would reduce much of the maintenance load.

No ground support equipment would be required by the logistically ideal aircraft for normal operations. The aircraft would have a self starting capability with an on-board auxiliary power unit (APU) to handle the electrical requirements before engine start. Deployments and dispersals would be easier with this capability in that it would reduce the amount of maintenance material and personnel that would have to accompany an aircraft when it is dispersed.

The design of the logistically ideal aircraft will be toward the goal of having only generalist maintenance personnel required for normal operations. An airplane general (APG) mechanic should be able to do all on-aircraft maintenance including troubleshooting of subsystem problems

and removal and replacement of faulty units. Specialists should be required only in field repair facilities and depots to handle off-aircraft repairs of faulty units and subsystems. The maintenance crew chief should not have to go beyond the maintenance bay and deep into the subsystem to troubleshoot and repair the aircraft. He should be able to do all but the most complex work which would be referred to field repair facilities. Reliance on generalist maintenance would increase the supportability of deployed and dispersed aircraft in wartime scenarios. During peacetime, it would help reduce the problems of maintaining a wing of aircraft. Generalist maintenance requirements would be beneficial in handling the peaks and valleys of the maintenance workload. In both cases, maintenance flexibility would be increased and a large, unwieldy maintenance burden on commanders would be reduced.

Flight crew, or pilot, performed maintenance will not be incorporated in the aircraft. There are not enough training hours available to keep an individual current in flight duties under various scenarios and also qualified to handle aircraft maintenance. The extent to which repairs should be accomplished by the pilot is to reroute functions to back-up systems but the pilot/crew cannot be expected to make repairs to the faulty system.

Automated Test Equipment (ATE) on, and for, the logistically ideal aircraft would be standardized for all

aircraft. This would result in personnel needing only to learn about test equipment once. The complexity of the ATE would be transparent to the maintenance worker. He would perform remove and replace maintenance and the ATE could be updated to include differing operational and environmental requirements. False alarm rates would be minimal and ideally a readout would be available that would isolate and identify the specific problem that is being encountered. In addition, the fastest and most efficient method of repairing that fault would be displayed to the maintenance worker.

This description of a logistically ideal aircraft would result in the elimination of many of the problems currently encountered in Air Force aircraft. While not freeing tactical commanders of logistical burdens involved in aircraft operations, incorporation of these features would reduce their reliance on logistics support. The flexibility of senior commanders would be greatly increased since many restrictions and problems of deploying and employing aircraft in potential battle zones would be eliminated.

V. Conclusions

The ultimate logistics goal is the elimination of all required support for aircraft. Barring battle damage or aircraft accident, the aircraft would need no maintenance action prior to or upon return from a mission. The aircraft would be parked by an incoming crew and be ready for immediate departure with a fresh crew. No servicing or maintenance would be required.

Operational commanders would be relieved of a great logistical burden which normally greatly impacts operational planning. Long logistics pipelines from forward areas back to the United States would be greatly reduced. Airlift support requirements for operational deployments would be reduced. Overall mission capability would be enhanced. The availability of aircraft would be improved since there would be no down time for re-arming and servicing. The effectiveness of the unit would be enhanced.

The description of this aircraft was not accomplished by this research. This study examines the major logistics problem areas of current aircraft. In searching for ways to avoid these problems in the future questionnaire responses tended to follow current thinking. The responses focused on how to improve systems that now exist, not on ways of possibly eliminating systems altogether. For example, there was discussion on the problems of aircraft wiring. Wiring problems are difficult to identify, trace, and repair on

current aircraft. A possible solution focused on segmenting wiring bundles into Line Replaceable Units. this would make repairs easier and faster. No comments, however, dealt with the possibility of eliminating wiring from an aircraft. Responses tended toward that which is currently feasible.

There are three possible reasons the responses may have been more parochial than intuitive. The first is the scope of the questions. The questions may have been too limited. They may have inadvertently directed attention toward parochial solutions. A second possible reason is perhaps the logistics experts are too narrowly focused on current problems and solutions. The experts may have a hard time disassociating themselves from their daily efforts in the logistics arena to back up and take a fresh look at where they would like to see things going in the future. A third possibility is a combination of both. The scope of the questions were too limited and the perspective of the selected logisticians was too narrow. This combination may have resulted in the short-range responses received.

The resulting aircraft description in the last chapter works to eliminate many of the logistics support problems of current aircraft but not their requirements. Periodic maintenance of some type is still required, as is servicing before and after a mission. Parts on this aircraft will wear out although failure rates would be lower and parts would be easier to replace.

The elements described would be a boon to operational commanders because they would eliminate much of the consideration of aircraft availability that affects operational planning. It would not go as far as to eliminate logistics support from tactical considerations but would do much to reduce it.

Recommendations

The task of describing a logistically ideal aircraft is of such magnitude that one research effort cannot give it sufficient attention to address all the evident issues. This study touches the surface but serves as a starting point for further research.

One possible research effort could be focused on expanding upon this study to draw out more futuristic ideas from other logistics experts. If they could be encouraged to completely disassociate themselves with current thought and project forward, perhaps a logistically ideal aircraft could truly be described. This would provide a target for logistics planners and weapons designers to work from.

Research could also be conducted on any of the particular areas described in the preceding chapter. For example, the avionics described could be studied in detail. So many subsystems were studied that none of them could be analyzed in detail. A research study with limited scope could carry out an in depth analysis of any one of the elements of the logistically ideal aircraft described in chapter 4.

Another research study could look at the cost/benefits of implementing the elements of a logistically ideal aircraft in the short-run. Naturally, additional funds would need to be expended up front prior to the fielding of an aircraft but the benefits of reduced maintenance action after the aircraft is fielded may outweigh the initial cost.

The logistically ideal aircraft is not a futuristic dream. This document should serve as a basis for specifying the ultimate logistical goal to be achieved. Once this goal is clearly identified, the means to achieving that goal can be found.

Appendix A: Round One Questionnaire

INSTRUCTIONS

1. OBJECTIVE

To solicit opinion as to what is important in the description of the logistically ideal aircraft for the 2000's and beyond.

2. GENERAL INSTRUCTIONS

- A. The following topics are not intended to be complete, exhaustive, or comprehensive. It is a partial list of topics designed to stimulate thought and generate ideas in a brainstorming manner.
- B. Your participation and thoughts are very important to the success of this research. Even incomplete or vaguely related ideas may stimulate the thoughts and contributions of other participants in subsequent iterations in which no names are used.
- C. This questionnaire is the first of three iterations. Each iteration should not take more than one hour to complete. Upon completion of each iteration, your responses will be tabulated and feedback will be provided for the following iteration. No names will be used.
- D. Following completion of the third iteration, the final results and comments will be provided to you. If you would like a copy of our completed thesis, please advise us so we may enter you on the mailing list.

3. SPECIFIC INSTRUCTIONS

- A. Please be as specific as possible as you respond to each question or statement.
- B. Please feel free to include any suggestions of alternate topics, further comments on selected topics, and/or your past experience which relates to the topics.
- C. Please feel free to continue comments on additional paper or the back of the questionnaire.
- D. The final page of the questionnaire is for additional topics or ideas not discussed in the questionnaire.

DELPHI TECHNIQUE

The traditional Delphi technique was developed for soliciting expert opinion on a variety of topics by the Rand Corporation. The technique uses a series of iterations to reach a consensus, or general consensus, on questions of a theoretical nature. Feedback is used to allow participants to revise their responses at any time or to continue with their previous responses.

Anonymity is one of the significant advantages of the Delphi technique. Anonymity is necessary to achieve the best exchange of information. The researchers request you refrain from discussing your participation in the Delphi process until the survey is completed.

1. AIRCRAFT SUBSYSTEMS: An aircraft consists of many subsystems (ex. airframe, engines, etc). List and rank order what you consider to be the top five subsystems as sources of logistic problems (Number one being the subsystem with the most logistic problems). Please explain your choices briefly.

2. AIRCRAFT COMPONENTS: Identify and rank order what you consider to be the top five aircraft components that cause logistics problems. Please briefly explain your choices.

In one or two sentences for each, how would you correct the problems identified above for systems? for components?

3. LOGISTIC AREAS: Logistics covers four main areas: supply, transportation, maintenance, and procurement. Please rank order these from the most to the least problems and briefly describe the major problems and why they exist.

4. FACILITY PROBLEMS: Identify and rank order the top five facility problems you perceive with respect to aircraft logistics and briefly explain why.

5. GROUND SUPPORT: Identify and rank order what you perceive to be the top five aircraft ground support equipment problems and briefly explain why.

6. DIAGNOSTIC CAPABILITY: Are some aircraft subsystems harder to troubleshoot than others? If so, identify and rank order the top five subsystems that have diagnostic capability problems and briefly explain why.

7. TRAINING: Do you consider the average aircraft maintenance person to be sufficiently trained and capable to accomplish their mission? Explain.

8. MAINTENANCE PERSONNEL: Should aircraft be designed so that flight line maintenance personnel should be specialists or generalists? Explain.

9. LOGISTICALLY IDEAL AIRCRAFT: What thoughts would you employ if you were assigned the task to describe the logistically ideal aircraft?

10. BATTLE DAMAGE: What design features should be incorporated in an aircraft to increase immediate repair capability for battle damage?

ADDITIONAL COMMENTS

Appendix B: Round Two Questionnaire

1. AIRCRAFT SUBSYSTEMS: An aircraft consists of many subsystems (ex. airframe, engines, etc). List and rank order what you consider to be the top five subsystems as sources of logistic problems (Number one being the subsystem with the most logistic problems). Please explain your choices briefly.

RESULTS: Eight individuals agreed that avionics is a major source of logistic problems and five individuals agreed that engines were one source of logistic problems. The following are the subsystems that were identified by at least two individuals, in order of agreement.

- Avionics
- Engines
- Hydraulics
- Landing Gear
- Airframe
- Electric/Power
- Fuel Systems
- Flight Control
- Fire Control
- Propulsion

Please review your previous response and, in light of the above information, reaccomplish question 1.

2. AIRCRAFT COMPONENTS: Identify and rank order what you consider to be the top five aircraft components that cause logistics problems. Please briefly explain your choices.

RESULTS: Five individuals agreed that components involving a black box/line replaceable units cause the most logistic problems while one individual indicated these problems will vary with individual types of aircraft. The following are the components that were identified by at least two individuals, in order of agreement.

- Black box/LRU
- Hydraulics, Pneumatics
- Fuel System components
- Radar
- Actuators
- Electronic components
- Fuel controls
- Connectors
- Avionics
- Landing Gear

Please review your previous response and, in light of the above information, reaccomplish question 2.

3. LOGISTIC AREAS: Logistics covers four main areas: supply, transportation, maintenance, and procurement. Please rank order these from the most to the least problems and briefly describe the major problems and why they exist.

RESULTS: Five individuals indicated the areas identified above do not adequately describe the logistics function. Other areas identified include: requirements determination, design data base, and computer aided design/computer aided manufacturing. One individual said all four areas identified above are of equal importance and cannot be distinguished by "most to least problems." Of the four areas identified, the rank order listing is as follows:

Maintenance
Supply
Procurement
Transportation

Please review your previous response and, in light of the above information, reaccomplish question 3.

4. DIAGNOSTIC CAPABILITY: Are some aircraft subsystems harder to troubleshoot than others? If so, identify and rank order the top five subsystems that have diagnostic capability problems and briefly explain why.

RESULTS: Seven individuals agreed that some subsystems are harder to diagnose than others. Two individuals disagreed. The following are the subsystems that were identified, in order of agreement.

- Avionics
- Engines/Bleed Air
- Radars
- Electrical
- Electronic warfare
- Instrumentation
- Communications
- Flight controls
- Environmental systems

Please review your previous response and, in light of the above information, reaccomplish question 4. (question 6 in the first iteration)

5. TRAINING: Do you consider the average aircraft maintenance person to be sufficiently trained and capable to accomplish their mission? Explain.

RESULTS: Three individuals agreed that the average aircraft maintenance person is sufficiently trained, while five individuals disagreed. One individual stated it was a function of the maintenance skill area. The following reasons were given:

- sufficient training but with a newly introduced system there is a lag while personnel learn.
- sufficient formal training, but need aggressive OJT.
- sufficient training, overall
- all should be trained as APS's first. Then after their first reenlistment, specialize as necessary.
- only trained enough to be dangerous in the technical schools and then turned loose with insufficient flight line supervision. There should be an automated engineering data base to lead the technicians step-by-step in repairing.
- Abolish FTO.
- maintenance is overly weighted toward first-term airmen. We need retention of experienced NCO's on the flight line.
- crew chiefs get only 35 days of familiarization at Sheppard AFB before being sent to the unit.

Please review your previous response and, in light of the above information reaccomplish question 5. (question 7 in the first iteration)

6. MAINTENANCE PERSONNEL: Should aircraft be designed so that flight line maintenance personnel should be specialists or generalists? Explain.

RESULTS: Eight individuals agreed that maintenance personnel should be generalists while one individual indicated that maintenance personnel should be specialists. The following reasons were given:

- too many under-utilized specialists now
- current specialist structure a burden to wartime commanders.
- need a few, backup specialists.
- start as a specialist, but move to a generalist as the individual's experience/grade increase.
- need generalists to support wartime dispersals but too much time is required to adequately train a generalist given the complexity of the weapon systems of today.
- a broader area of maintenance knowledge will help in handling the peaks and valleys of the maintenance workload.
- APB's should handle all on-equipment maintenance. Specialists should handle off-equipment maintenance in field repair facilities and depots. This would cut Air Force maintenance manpower requirements by at least 50 percent.

Please review your previous response and, in light of the above information, reaccomplish question 6. (question 8 in the first iteration)

7. COMPLEXITY: Should we have many simple, inexpensive, limited capability aircraft or a few, complex, expensive, multipurpose aircraft? Explain.

8. DESIGN: Should an aircraft be designed with the idea of pilot performed maintenance in mind? Explain.

9. FUTURE SERVICE: The number of teenagers eligible for military service is predicted to decline by 24% over the next two decades. Will this impact the role of logistic supportability for aircraft? If so, what should be considered in aircraft design to overcome this problem?

10. ATE: Identify the major advantages and disadvantages of increased use of Automated Test Equipment (ATE) at the different levels of Air Force maintenance.

ADDITIONAL COMMENTS

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Captain John O. Campbell was born on 27 January 1954 in Los Angeles California. He graduated from the Air Force Academy in 1976 with a Bachelor of Science degree in Engineering Sciences. His first assignment was to Undergraduate Pilot Training (UPT) at Columbus AFB, Mississippi. He was an Outstanding Graduate from UPT and won the ATC Flying Training Award. He attended Combat Crew Training School at Castle AFB, California, to transition to the KC 135 aircraft. There, he was also a Distinguished Graduate. He was assigned to the 912th Air Refueling Squadron, Robins AFB, Georgia as a co-pilot and then aircraft commander from 1978 to 1983. He was awarded the Air Force Commendation Medal in 1983. In 1983, he was selected to attend the Air Force Institute of Technology in a Master of Science program. He is married to the former Lynn Hoffman and has three children: John, age 5; Daniel, age 2; and Nicholas, age 1.

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The purpose of this ^{thesis} research was to develop a description of a logistics ideal aircraft. A survey was conducted of senior Air Force logisticians and distinguished civilian logisticians. The Delphi methodology was used to elicit expert opinion concerning major logistics problems in current generation aircraft and ways to avoid these problems in future generation aircraft. These problems and solutions were used to describe the logistics ideal aircraft.
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